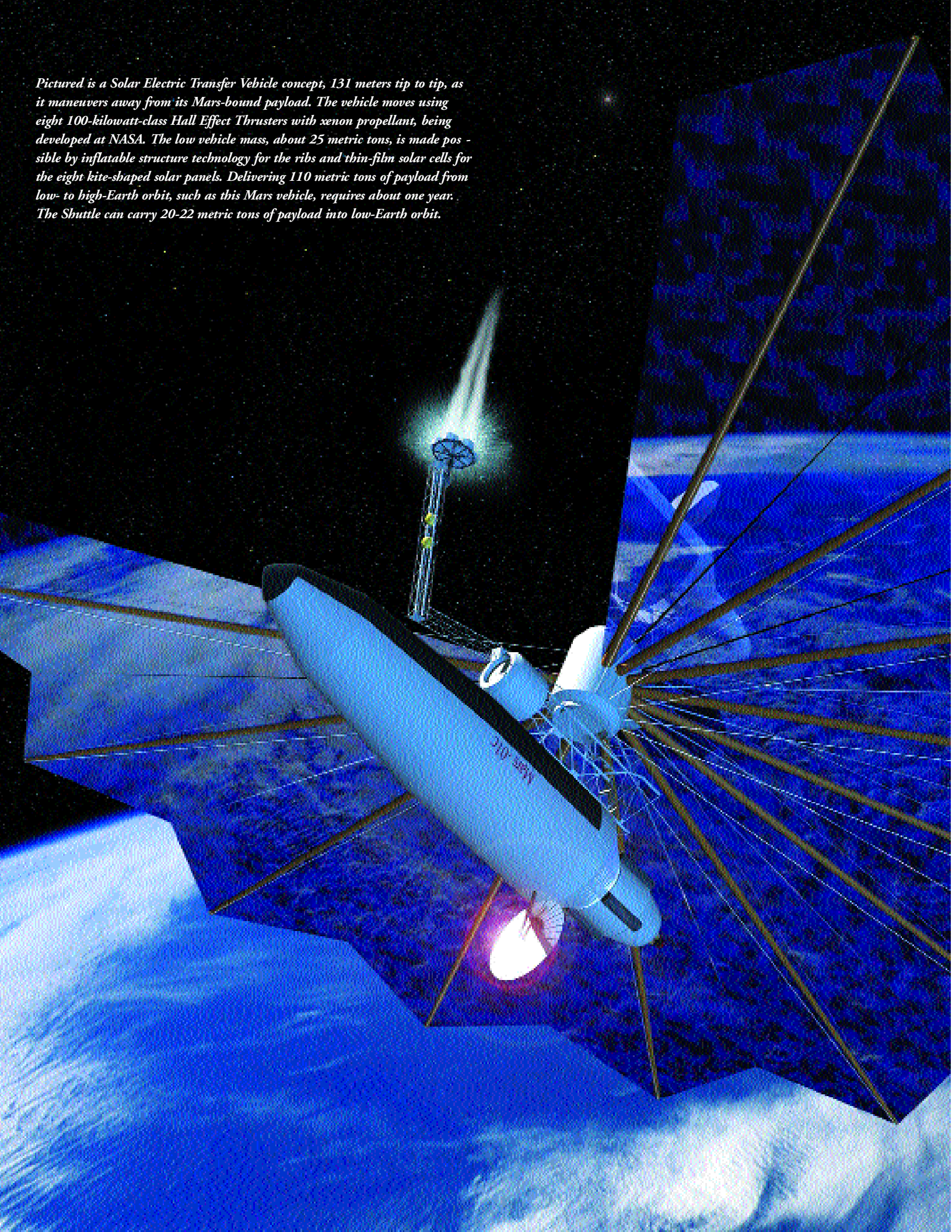


Pictured is a Solar Electric Transfer Vehicle concept, 131 meters tip to tip, as it maneuvers away from its Mars-bound payload. The vehicle moves using eight 100-kilowatt-class Hall Effect Thrusters with xenon propellant, being developed at NASA. The low vehicle mass, about 25 metric tons, is made possible by inflatable structure technology for the ribs and thin-film solar cells for the eight kite-shaped solar panels. Delivering 110 metric tons of payload from low- to high-Earth orbit, such as this Mars vehicle, requires about one year. The Shuttle can carry 20-22 metric tons of payload into low-Earth orbit.



Goal Two: Advance Space Transportation

NASA'S GOAL IS TO CREATE A SAFE, AFFORDABLE HIGHWAY THROUGH THE AIR AND INTO SPACE.

Revolutionizing our space transportation system to significantly reduce costs and increase reliability and safety will open the space frontier to new levels of exploration and commercial endeavor. With the creation of the Integrated Space Transportation Plan (ISTP), the Agency defined a single, integrated investment strategy for all its diverse space transportation efforts. By investing in a sustained progression of research and technology development initiatives, NASA will realize its vision for generations of reusable launch vehicles and in-space transportation systems that will surmount the Earth-to-orbit challenge and transport us to our neighboring planets and the stars beyond.

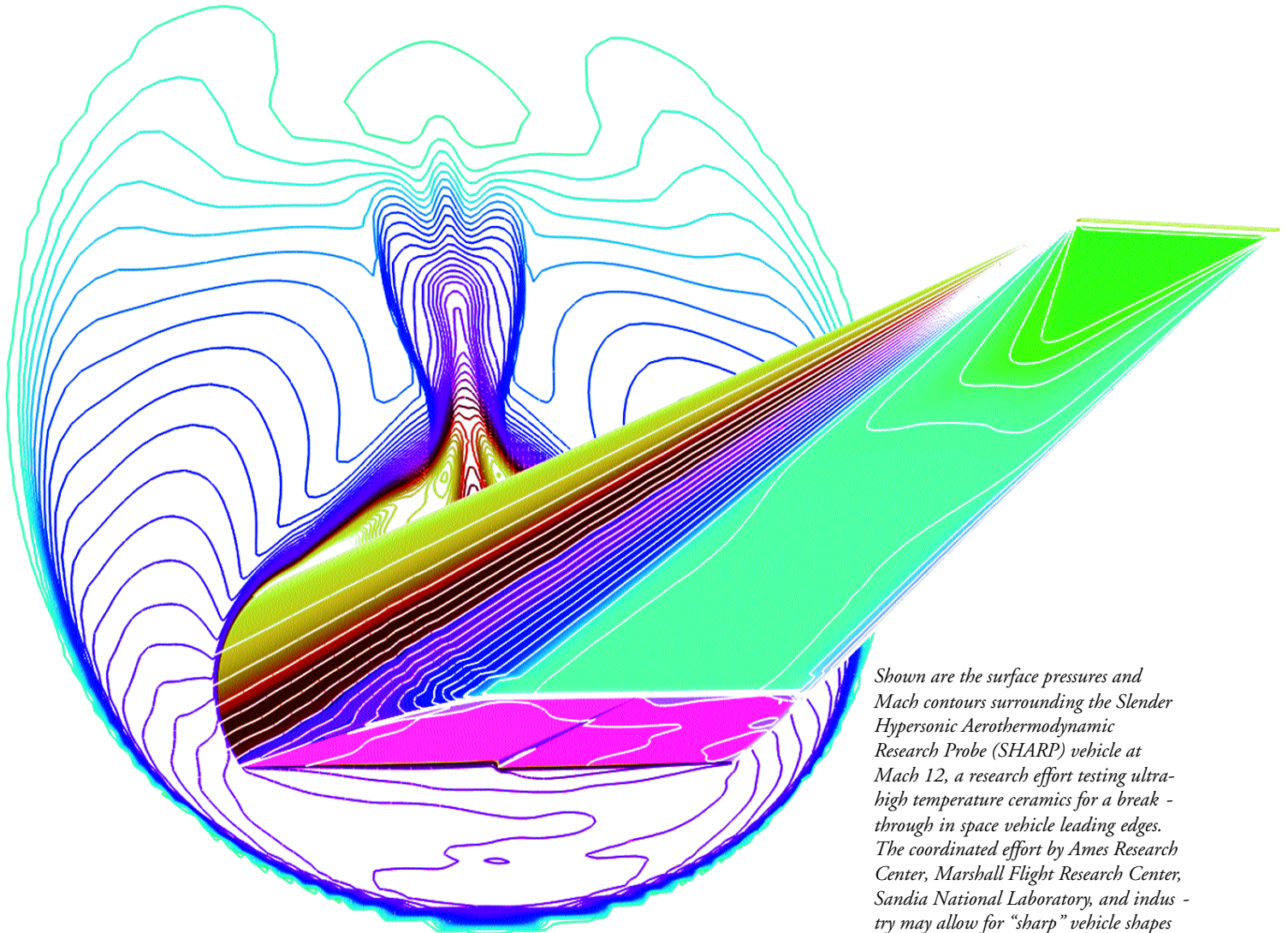
Objective 6: Mission Safety

Radically improve the safety and reliability of space launch systems.

Reduce the incidence of crew loss for a second generation Reusable Launch Vehicle (RLV) to 1 in 10,000 missions (a factor of 40) by 2010 and to less than 1 in 1 million missions (an additional factor of 100) for a third generation RLV by 2025.

Achieving the long-term goal translates to an advanced space transportation system with an accident rate roughly equivalent to that of today's commercial aviation system. A significant increase in the performance margin of launch systems is fundamental to achieving this objective. NASA is working to reduce the risk of crew loss by

designing for inherent vehicle safety and reliability, with fewer parts and more robust subsystems. Integrating intelligence into vehicle systems will result in improved vehicle health management and self repair. The development of tools that will enable end-to-end computer design and testing of an entire vehicle and its mission, including life cycle risk assessment, will dramatically



Shown are the surface pressures and Mach contours surrounding the Slender Hypersonic Aerothermodynamic Research Probe (SHARP) vehicle at Mach 12, a research effort testing ultra-high temperature ceramics for a breakthrough in space vehicle leading edges. The coordinated effort by Ames Research Center, Marshall Flight Research Center, Sandia National Laboratory, and industry may allow for "sharp" vehicle shapes that can withstand the high temperatures of atmospheric reentry. Not only good for efficiency, it would also allow more maneuverability and vehicle range, which greatly increases safety and reliability for crew return vehicles.

Objective 6: Mission Safety

NASA's strategy for achieving this objective is to pursue the following technology thrusts:

- **REUSABLE AND ROBUST PROPULSION SYSTEMS**—Develop technologies for inherent reliability, more robust subsystems, and an increased performance margin for propulsion and power systems.
- **INTEGRATED VEHICLE HEALTH MANAGEMENT (IVHM)**—Develop advanced sensors and algorithms to integrate intelligence, such as real-time failure detection and isolation, into vehicle systems.
- **CREW ESCAPE**—Develop systems to remove the crew safely from a vehicle in the event of catastrophic failure during the highest risk phases of a mission, including vehicle ascent and descent.

Metrics associated with these thrusts include crew survivability and reduced mission loss.



Marshall Space Flight Center and Boeing plan to build and fly the X-37 reusable vehicle to demonstrate a wide range of enabling technologies for reducing the cost of access to space while increasing safety and reliability. The X-37 will operate and provide data in both orbital and re-entry phases of flight. Current planning includes 31 embedded technologies and 8 NASA/Air Force experiments.

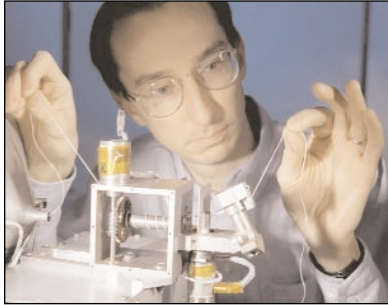
Outcomes

Successful research and development efforts that lead to new vehicles and operational practices would result in:

- Intelligent, reliable systems and subsystems.
- Increased safety margins for all systems.
- Highly robust systems that can tolerate multiple failures and still complete the mission.
- Fast, efficient identification of abnormal conditions to increase the time available for corrective actions.
- Systems to protect human life in the event of unavoidable failure of a vehicle or launch system.

Key Strategy and Partnership Issues

The approach for second-generation reusable launch vehicle systems will be to develop and maintain system level requirements to meet safety, cost, and reliability goals. Assessing the impact of subsystem requirements on these integrated system level requirements is key to ensuring that the overall architecture remains commercially competitive and affordable. The integrity of the requirements will be maintained by using integrated systems engineering, prioritizing technology investments, and managing the convergence of commercial and civil space needs. Within this framework, investments for the purpose of risk reduction will be pursued to optimize factors for robust safety margins, reliability, redundancy, operational procedures, crew escape, and embedded intelligence. For third generation vehicle systems and beyond, a broad suite of the most promising technologies that enhance safety will be pursued. We will work closely with our industry, DoD, and academic partners to accelerate the development of enabling technologies and vehicle designs.



NASA's Propulsive Small Expendable Deployer System (ProSEDS) will be the first demonstration of a propellant-free space propulsion system. Les Johnson, of Marshall Space Flight Center, inspects the nonconducting part of a tether as it exits a deployer similar to the system in the ProSEDS flight experiment. This propulsion system, if applied to maintaining the International Space Station's operating orbit, could potentially save more than \$1 billion over ten years.

Objective 7: Mission Affordability

Create an affordable highway to space.

Reduce the cost of delivering a payload to Low-Earth Orbit (LEO) to \$1000 per pound (a factor of 10) by 2010 and to \$100 per pound (an additional factor of 10) by 2025. Reduce the cost of interorbital transfer by a factor of 10 within 15 years and by an additional factor of 10 by 2025.

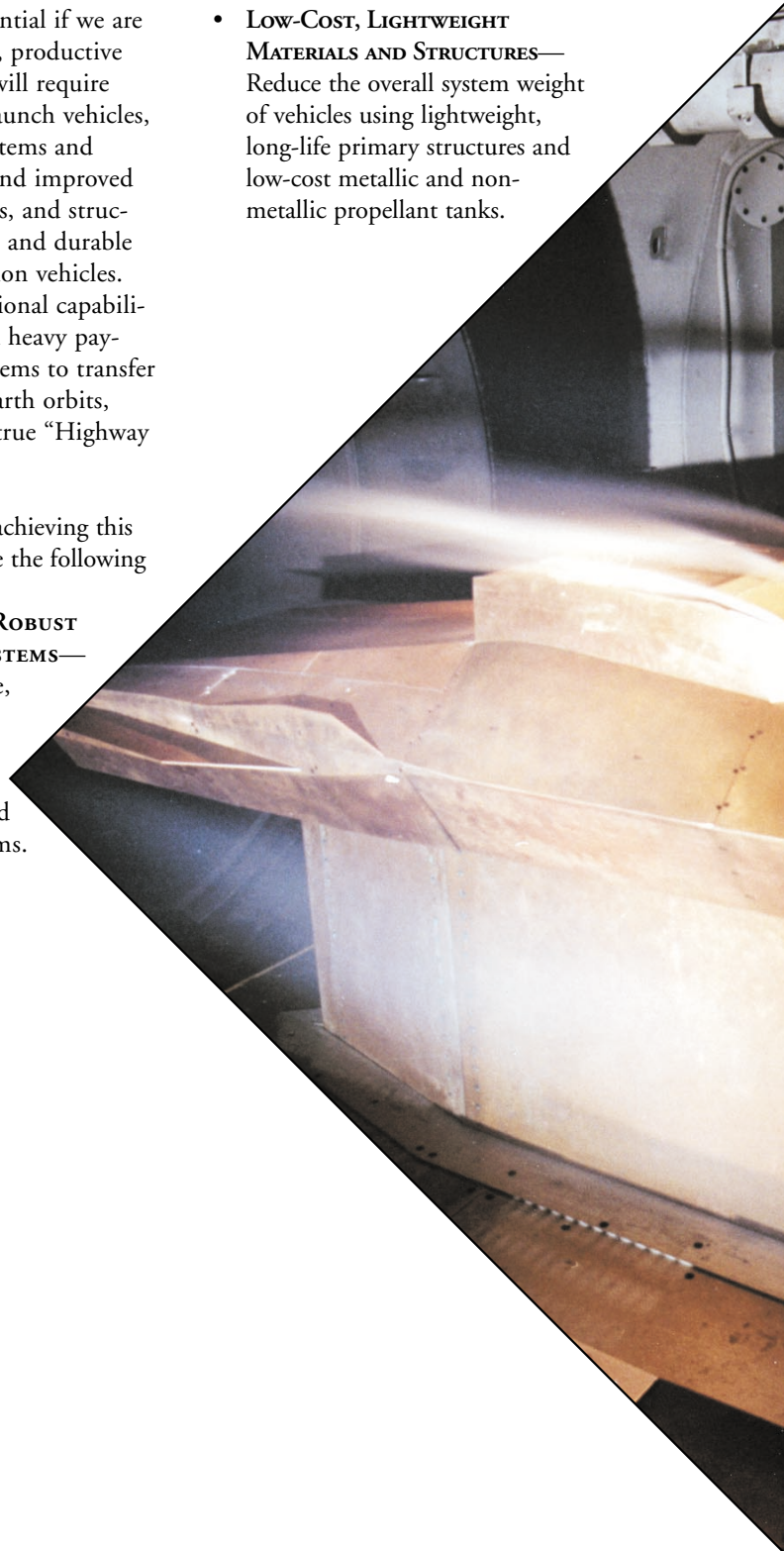
Achieving this objective will enable payload delivery to LEO for \$100 per pound, a dramatic reduction from the approximate \$10,000 per pound that it costs today. We also seek to reduce the overall cost of delivering payloads to their final destination at a higher orbit. In both cases, the cost reduction must occur without compromising safety or reliability. Safety, reliability, and

affordability are essential if we are to realize a dynamic, productive space market. This will require improved reusable launch vehicles, advanced launch systems and launch operations, and improved propulsion, materials, and structures for lightweight and durable in-space transportation vehicles. By developing additional capabilities for medium and heavy payloads, including systems to transfer payloads between Earth orbits, NASA will create a true "Highway to Space."

NASA's strategy for achieving this objective is to pursue the following technology thrusts:

- **REUSABLE AND ROBUST PROPULSION SYSTEMS—**
Develop long-life, highly reusable engine systems and inherently reliable integrated propulsion systems.

- **LOW-COST, LIGHTWEIGHT MATERIALS AND STRUCTURES—**
Reduce the overall system weight of vehicles using lightweight, long-life primary structures and low-cost metallic and non-metallic propellant tanks.



Objective 7: Mission Affordability

- **OPERATIONS OPTIMIZATION**—Develop the capability for autonomous checkout and vehicle control, modular payload systems, and new launch site operations.

- **RISK REDUCTION**—Develop key technologies for full-scale development of a second-generation RLV system.

Metrics for measuring impact on mission affordability include customer cost per pound and cost to final destination.

Outcomes

Successful research and development efforts that lead to new vehicles and operational practices would result in:

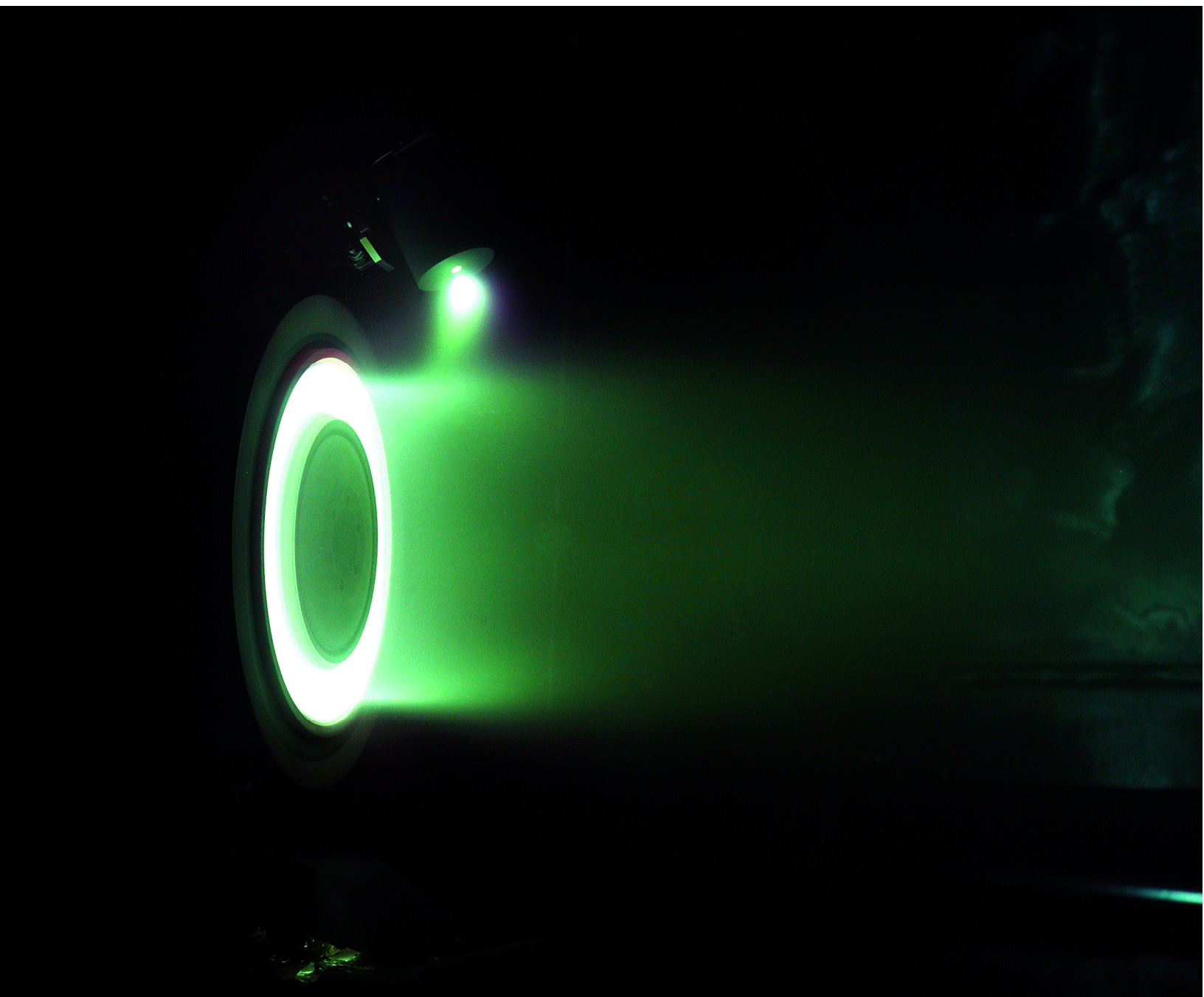
- An integrated space transportation architecture to optimize mission success and minimize cost to the final orbital destination.

- Advanced, reusable, and robust transportation systems.
- Reduced for vehicle turnaround time inspection and increased launch operation efficiency.
- The creation of new markets and new uses for space.

Key Strategy and Partnership Issues

The strategy is to accelerate the development of key technologies, to create lower-cost reusable launch vehicles, and to continue our investment in areas of long-term research to enable the development of third and fourth generation launch vehicle systems. The approach to lower-cost, second-generation reusable launch vehicle systems is parallel to safety efforts. Using systems engineering, NASA will manage requirements, prioritize technology investments, manage the convergence of commercial, civil, and military space needs, and maximize technology partnership opportunities. For third-generation vehicle systems and beyond, a broad suite of the most promising technologies for reducing overall space transportation costs will be pursued. We will work closely with industry, DoD and academic partners to accelerate the development of enabling technologies and vehicle designs.

Flight of the X-43 vehicle will be the first time a non-rocket engine has powered aircraft at hypersonic speeds (over 3,600 miles per hour at sea level), significantly expanding the boundaries of air-breathing aircraft. Unlike a rocket that must carry its own oxygen for combustion, the X-43's air-breathing engine scoops oxygen from the atmosphere. Without onboard oxygen, the vehicle is lighter and able to carry more cargo/payload than rocket-powered propulsion vehicles creating the potential for a more capable, affordable and versatile launch vehicle. X-43 flight tests up to Mach 10, or ten times the speed of sound, are being performed at the Dryden Flight Research Center. The spare X-43 flight engine is shown during a full test of its flight conditions in the Langley Research Center's 8-Foot High Temperature Tunnel, to measure engine performance for comparison with the flight data.



Between April and August of 2000, a 10-kilowatt Hall effect thruster, designated T-220, was subjected to a 1000-hour life test evaluation in Vacuum Facility #12 at Glenn Research Center. Hall effect thrusters are propulsion devices that electrostatically accelerate xenon ions to produce thrust. The T-220 performed well throughout the test (doubling the 500-hour goal), with discharge current oscillations and propellant use improving over time. The T-220 produces enough thrust to enable efficient orbital transfers, saving hundreds of kilograms in propellant over conventional chemical propulsion systems.

Objective 8: Mission Reach

Objective 8: Mission Reach

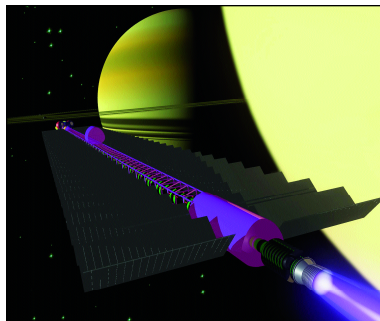
Extend our reach in space with faster travel.

Reduce the time for planetary missions by a factor of 2 by 2015 and by a factor of 10 by 2025.

This objective aims to develop light, rapid space propulsion systems that will reduce travel times. Technology focus areas include small systems for traveling to other planets and “breakthrough” propulsion technologies to allow missions to reach other stars within a human life span.

NASA’s strategy for achieving this objective is to pursue the following technology thrusts:

- **ADVANCED PROPULSION CONCEPTS**—Identify and develop breakthrough technology for advanced propulsion systems.
- **MATERIALS AND STRUCTURES**—Develop lightweight airframes, tanks, and micro-components using nano-technology and ultra-high temperature ceramics.



An artist's concept of a fusion-powered space vehicle approaching the Saturn moon Titan.

Metrics include days to final destination, propulsion system mass, and vehicle system mass.

Outcomes

Successful research and development efforts that lead to new vehicles and operational practices would result in:

- Major increases in propulsion system performance and capability.
- A major reduction in overall vehicle system size and mass.
- Improvements in overall vehicle performance.

Key Strategy and Partnership Issues

We will work closely with NASA’s Enterprises for Space Science, Earth Science, and the Human Exploration and Development of Space, as well as commercial customers to plan our technology efforts alongside their mission roadmaps. In order to achieve NASA’s ambitious space exploration missions over the next several decades, revolutionary materials, structures, and in-space propulsion technologies must be developed. Close coordination with the Enterprises will enable timely research, development, and application of key technologies to support their missions.